Dental age estimation of living persons: Comparison of MRI with OPG

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ABSTRACT

The need for forensic age estimations in living adolescents is high mainly due to migration, particularly from countries where birth dates are not reliably documented. To date, the gold standard of dental age estimation is the evaluation of the mineralization and eruption stages of the third molars using an orthopantomogram (OPG). However, the use of ionizing radiation without medical indication is ethically controversial and not permitted in many countries. Thus, the aim of this study was to investigate if dental MRI can be used for the assessment of dental age with equally good results as when using an OPG.

27 healthy volunteers (19 ♀, 8 ♂, age range 13.6–23.1 years, median 18.9 years) underwent an MRI scan of the jaw after a clinically indicated OPG. Mineralization and eruption stages of the molars were independently analyzed on OPGs and MRI by two blinded dentists according to the staging system established by Demirjian and Olze, respectively. The results of OPG and MRI were compared and inter-rater agreement was determined.

The developmental stages of the 262 evaluated molars could be clearly differentiated in MRI. For both, mineralization and eruption, there was a good correlation between MRI and OPG. Overall MRI tended to yield slightly lower stages than the OPG. Inter-rater agreement was moderate for mineralization and good regarding eruption.

Although a validation of these results using modality-specific reference values is needed, dental MRI seems to be suitable for a use in dental age estimation.

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1. Introduction

Due to migration, the recent years have brought a significant rise in the need for forensic age estimations in living people, particularly from countries where birth dates are not reliably documented. Age estimations are important in asylum regulations, as there are different judicial procedures depending on the age of a person. However, forensic age estimation is also an important aspect in civil or penal law procedures.

To date the recommended procedure for forensic age estimations in adolescents [1–3] involves an external examination of the

body, and the assessment of the stage of the skeletal and the dental development. Dental age estimation in the age range of legally relevant age thresholds of European countries between 13 and 21 years is based on the development of the third molars, which is usually performed by evaluating a panoramic X-ray, i.e., an orthopantomogram (OPG) [3]. A number of staging systems have been established using various morphological criteria of tooth development [4–6]. One well known approach is based on the assessment of the mineralization [4,7] and the eruption of the third molars [8]. Based on published reference values for each stage and for different populations [9–14], the evaluated stages are then converted into an age estimate in years. While staging systems and reference values are subject to ongoing research and optimizations, the basis for the evaluation of dental development has become an issue in recent years. The main reason is that the OPG is based on ionizing radiation, which in many countries is legally prohibited for non-clinical indications. Additionally, with increased public sensitization for health issues, the use of ionizing

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radiation has become ethically controversial. Magnetic resonance imaging (MRI) is not based on X-rays and is not associated with an exposure to ionizing radiation. Additionally, it could offer further advantages regarding the evaluation of the images being free of superposition and allowing 3D post processing. To date, dental MRI is not often used in clinical dentistry even if there exist some initial studies, e.g., to detect dental abnormalities and dental illnesses as well as abnormalities of the jaw [15–17], and has been shown to be suitable for children and adolescents [18].

The aim of this study was to investigate if the previously defined stages of mineralization [4,7] and eruption [8] can be assessed in dental MRI, and to elucidate the differences between dental MRI and OPG data concerning the assessed stages.

2. Materials and methods

2.1. Study design

The design of the study was a prospective cross-sectional evaluation comparing dental MRI with OPGs.

2.2. Subjects

Twenty-seven healthy caucasian volunteers (19 females, 8 males) living in Austria with a chronological age between 13 and 24 years (females: median 20.0 years, age range 13.5–23.1 years; males: median 17.0 years, age range 13.7–21.3 years) with at least two present third molars underwent an MRI scan of the jaw within 14 days after a clinically indicated OPG. The local ethics committee approved the study, and informed consent was obtained from each volunteer and additionally from a parent, in case the volunteer was a minor. The data were collected over a period of 13 months.

2.3. Imaging

MRI examinations were performed on a 3 T scanner (Magnetom Trio, a TIM System, Siemens AG, Erlangen, Germany) using an 8-channel multifunctional coil (CPC, Noras MRI products GmbH, Höchberg, Germany). The protocol consisted of a 3D TSE sequence (TR/TE 172/10 ms, resolution 0.6 mm × 0.6 mm × 1.0 mm) and a 3D constructive interference in steady state (CISS) sequence (TR/TE 5.41/2.33ms, FA = 30°, resolution 0.6 mm × 0.6 mm × 1.0 mm). The total acquisition time was 20:31 min. The coil was placed on both sides of the face, covering the upper and lower jaw, with particular focus on the posterior parts. Both sequences were performed with two slabs angulated along the jaw.

The OPGs covering full upper and lower jaw were taken in the course of medical care at the Department of Oral Surgery and Radiology at the University Hospital. All OPGs were performed according to standard dental practice using a digital panoramic radiography device (Orthophos XG plus DS, Sirona Dental Systems GmbH, Bensheim, Germany) with 60–70 kVp and 14–17 mA.

2.4. Dental evaluation

The MR images and the OPGs were separately and independently read by two dentists (H.M., J.B.). The presence of the wisdom teeth and their eligibility for assessment regarding image quality and dental position were considered for each modality. If quality hampered proper evaluation by both observers due to technical reasons such as artifacts or superpositions, the concerned tooth was excluded from further analysis. Image quality was judged as good, if the dentists recognized the different criteria they needed to assess the corresponding stage of mineralization and eruption, respectively. No given quality scale was applied.

Mineralization and eruption stages of the molars of all four quadrants (teeth 16, 17, 18; 26, 27, 28; 36, 37, 38; 46, 47, 48) were evaluated, based on the fact that good visibility of dental and periodontal structures had been demonstrated using MRI [16]. Mineralization was assessed according to the staging system established by Demirjian and Mincer using the stages A–H [4,7,19], eruption was evaluated using the stages A–D according to Olze [8]. The evaluation was done using a multi-modality work place (syngoMMWP VE31A, SiemensAG, Erlangen, Germany) and an open-source DICOM viewer software (OsiriX 4.1, http://www.osirix-viewer.com). The examiners were blinded to the date of birth of the volunteers and to the scores of each other.

2.5. Statistical analysis

For statistical analysis Microsoft Office Excel 2007 (Microsoft Corp., Redmond, WA, USA) and the open-source software R (v3.0.2, www.r-project.org) were used.

2.5.1. Comparison of the stages in MRI with those of the OPG

For all investigated molars the results of examiner (H.M.) were used. For evaluation, the mineralization stages A–H were assigned the scores 1–8, and the eruption stages A–D the scores 1–4, respectively. Linear regression and Pearson's correlation coefficient r were calculated, and Bland Altman plots were performed [20]. Additionally, the agreement of the stages for mineralization and eruption in MRI and OPG was calculated in percent.

2.5.2. Inter-observer agreement

The results of the two examiners were compared and unweighted Cohen's Kappa was calculated for the assessment of inter-rater agreement.

3. Results

3.1. Evaluated data

After the exclusion of one volunteer from the evaluation, due to the OPG being more than 14 days old, a total of 312 data sets of individual molars in 26 subjects (18 females, 8 males; median age 18.89 years, range 13.56–23.11 years) were evaluated by the two observers.

For the analysis of inter-observer agreement, all 312 data sets including possibly missing molars were considered, whereas for the comparison of OPG and MRI data with each other only present molars were assessed, i.e., 307 molars as 5 molars were missing. Additionally, some teeth were excluded from further analysis due to technical reasons such as overlaps and imaging artifacts. Concerning mineralization 34 molars, predominantly of the upper jaw, could not be assessed in the OPGs while in the MRI data only 15 molars, equally distributed among upper and lower jaw, could not be evaluated. In contrast, concerning eruption 13 molars, predominantly of the lower jaw, could not be evaluated in the OPGs while 33 molars, mostly of the lower jaw, could not be assessed in the MRI data.

Overall, 262 molars were used for the assessment of mineralization in both, OPG and MRI data, and 274 for the evaluation of eruption.

As shown in Fig. 1 it was possible to identify the different developmental stages in good quality in the OPG as well as in the MRI data. The two MRI sequences were considered to be of equally good usability by both examiners. In the investigated study sample, only mineralization stages higher than B (stages C–H) were found.